3 SYSTEM ENGINEERING IN THE ACQUISITION MANAGEMENT SYSTEM PROGRAM LIFECYCLE

3.1 Introduction

This chapter discusses the relationship between the System Engineering (SE) milestones and the phases and lifecycle management decisions of the Acquisition Management System (AMS). The inputs and outputs for each SE element are related to each (AMS) phase through the SE milestones shown in Figure 3.3-1, and the elements and products are associated with the AMS decision points.

This System Engineering Manual (SEM) reflects industry and government SE standards, methodologies, and best practices. It recognizes that the current state of the referenced AMS, SE documents, and processes herein may not be in total agreement because that documentation and the SEM are in different update cycles. This version of the SEM reflects the changes that have been made to the AMS to incorporate the Office of Management and Budget (OMB) Exhibit 300 process.

This chapter includes graphical depictions of the inputs, SE activities, and outputs of each AMS phase. Tailoring guidance for the SE process to a particular program that was contained in this chapter in previous versions of the SEM is now found in Section 4.14, System Engineering Process Management.

3.1.1 The FAA Lifecycle Management Process

Figure 3.1-1 depicts the FAA AMS Lifecycle Management Process.

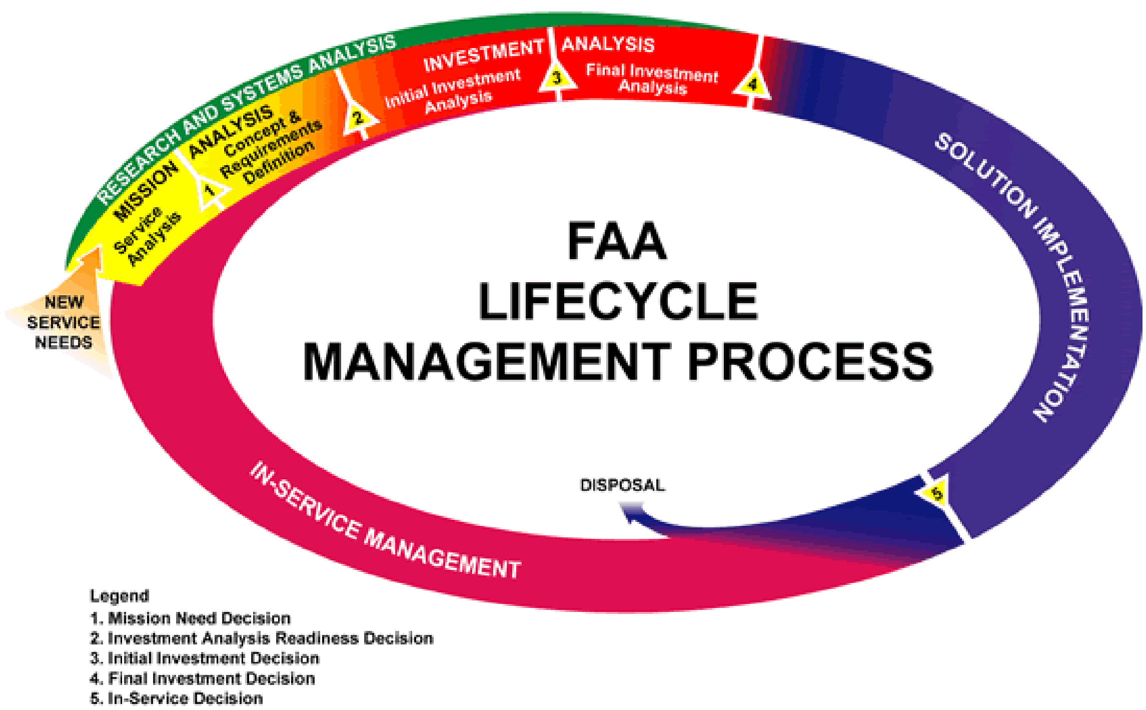

Figure 3.1-1. FAA AMS Lifecycle Management Process

The process contains five major decision points at which the Enterprise investment authority may make decisions to continue or cancel the program based on performance or other factors.

SE is conducted and documented throughout the lifecycle process, which spans individual investment programs across the National Airspace System (NAS). SE ensures integration across the NAS for service-level capabilities to achieve an efficient and fully interoperable NAS. At the program level, SE optimizes performance, benefits, operations, and lifecycle cost.

3.1.2 Relationships Between SE Elements

Chapter 1 (see Table 1.2-1) listed the SE elements. This chapter discusses the relationships among the SE elements by describing the inputs to and the outputs from the various elements. An approach describing these interrelationships uses an N-squared (N^2) diagram for the SE elements.

The **N^2 diagram** is a systematic approach to identify, define, tabulate, design, and analyze the relationships between the set of SE elements that comprise the FAA process defined in this SEM. It can also be used to characterize relationships between functional and physical interfaces. The "N" in an N^2 chart (an N x N matrix) is the number of entities for which relationships are shown. In this case, it is the set of 13 SE elements in Table 1.2-1. They appear along the diagonal axis. The remainder of the squares in the matrix contain interface inputs and outputs. The contents of each intersection of the rows and columns interconnecting any two elements indicate the interface between those elements in the form of inputs and outputs. The outputs appear on the horizontal rows, while the vertical columns indicate inputs. Data flows in a clockwise direction between elements. **Figure 3.1-2** shows the SE elements along the diagonal of the **N^2 diagram**, with the other matrix entries indicating the inputs, outputs, and product relationships between the SE elements by tracing the intersections of rows and columns.

Figure 3.1-2. System Engineering Functional N^2 Diagram

3.2 SE Elements and the AMS Lifecycle Phases

The program lifecycle includes all activities and products associated with a system, from initial concept to disposal. This aligns with the global aspects of SE's definition. Definitions of the program lifecycle phases serve different purposes for different SE elements. Table 3.2-1 shows the FAA SE elements and their association with each of the AMS phases.

Table 3.2-1. Relationship Between SE Elements and AMS Phases

SE Element / AMS Lifecycle Phase	Integrated Technical Planning	Requirements Management	Functional Analysis	Synthesis	Trade Studies	Interface Management	Specialty Engineering	Integrity of Analyses	Risk Management	Configuration Management	Validation and Verification	Lifecycle Engineering	Maintain System Engineering
Mission Analysis	X	X	X	X	X	X	X	X	X		X	X	
Investment Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X
Solution Implementation	X	X	X	X	X	X	X	X	X	X	X	X	X
In-Service Management	X	X	X	X	X	X	X	X	X	X	X	X	X
Disposal	X				X	X	X		X	X		X	

3.3 Associating SE Milestones With AMS Phases

SE reviews and milestones are associated with and support various AMS decision points. These SE milestones are the primary means to measure a program's progress. The reviews and milestones are detailed in subsection 4.2.6 (in Section 4.2, Integrated Technical Planning) and summarized in the following paragraphs (by AMS decision point):

- **Mission Need Decision (AMS-1).** In support of the AMS-1 decision point, analysis is conducted to determine what capabilities must be in place now and in the future to meet agency goals and the service needs of stakeholders. The primary analysis output is a service-level mission need for each service organization. The major SE input to this decision is a recommendation on candidate technologies to be considered and an identification of the shortfall to be addressed. The candidate technology recommendation is an output of a Technology Readiness Assessment (TRA).
- **Investment Analysis Readiness Decision (AMS-2).** Subsequent to the AMS-1 decision, a concept and requirements development activity is conducted, which results in an Investment Analysis Readiness Decision (IARD). SE provides inputs to this decision through the results of an SE Investment Analysis Review (SIAR), which determines if there is sufficient SE data available for a viable decision.
- **Initial Investment Decision (AMS-3).** The initial investment effort explores possible alternative technology or operational solutions to satisfy the mission shortfalls identified in AMS-1. The AMS-3 decision evaluates the most promising solution(s) for further refinement before a final decision. SE conducts a Functional Baseline Review (FBR) to support the Initial Investment Decision and establishes the functional baseline for the investment.
- **Final Investment Decision (AMS-4).** Completion of the Investment Analysis effort is marked by an investment decision. This decision point selects the actual solution in which to invest. A System Requirements Review (SRR) is conducted to validate that the program requirements are sufficient to support the investment decision.
- **In-Service Decision (AMS-5).** The In-Service Review checklist is reviewed by the appointed decision authority as part of the In-Service Decision. Several SE milestones, such as the Preliminary Design Review (PDR) and Critical Design Review (CDR), are established as quality gates leading up to this decision point.

3.3.1 SE Milestones and Products Associated With the Product Development Process

Figure 3.3-1 depicts the relationship between the SE milestones, associated SE products, and the AMS decision points for each AMS phase. The following subsections correlate the SE milestones with each phase and decision gate(s) of the AMS lifecycle shown in Figure 3.3-1. Data flow diagrams in subsequent figures highlight the SE processes and work products that are predominant during the associated AMS phase. See subsection 4.2.6 (in Section 4.2, Integrated Technical Planning) for further details on these reviews and milestones.

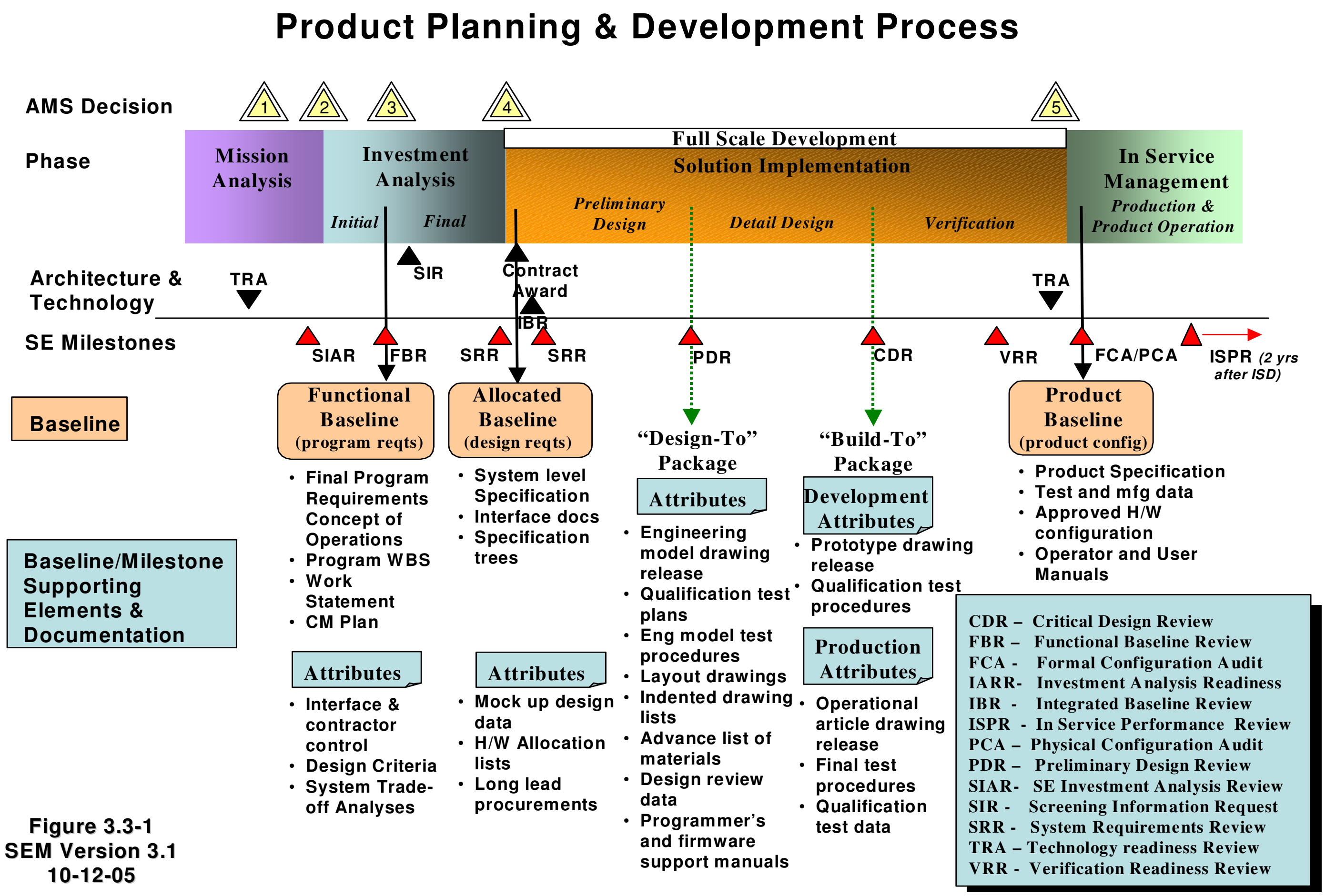

Figure 3.3-1 Product Planning & Development Process

3.3.2 FAA Framework

Table 3.3-1 further expands Figure 3.3-1 to:

- Identify the SE milestones and SE work product outputs associated with the SE milestone
- Show the AMS decision gates and relate the SE effort to these gates
- Account for the new Exhibit 300 products in the AMS and the SE contributions to these products

Table 3.3-1. FAA SE Lifecycle Framework

AMS Lifecycle Phase	SE Milestone Entry Criteria	SE Milestone	SE Milestone Output (SE Products Only)	AMS Investment Decision Gate
Mission Analysis				
Corporate	• Enterprise Architecture • Concept of Operations (CONOPS) • Concerns and Issues • Technology • Market Research • Need • Corporate Strategy and Goals • Legacy System	**Technology Readiness Assessment (TRA)** — A multi-disciplined technical review that assesses the maturity of Critical Technology Elements (CTEs) being considered to address user needs; analyzes operational capabilities and environmental constraints within the Enterprise Architecture (EA) framework.	• Validated NAS Functional portion of EA • Technology opportunities • Updated Risk Assessment • Gap Analysis	
Service level	• CONOPS • Gap Analysis • Standards • Guidance and Tools for Service level MA		• Functional Architecture • Service Level Mission Need (SLMN)	**1. Mission Need Decision *(new)***
Concepts and Requirements definition	• Preliminary Concept of Use (CONUSE) • FAA Policy • Standards • Preliminary Operational Services and Environmenta l Description (OSED) • Constraints • Integrated Program Schedule • Initial Description of	**SE Investment Analysis Review (SIAR)** — A review to determine if the mission need capabilities shortfall and attendant solution set of alternatives (i.e., a valid set of concepts and preliminary requirements, technical constraints, and the list of risks) are complete enough to support a Mission Need Decision.	• Preliminary Exhibit 300 Attachment 1 (preliminary Program requirements (pPR) — previously the Initial Requirements Document (iRD) • Final Description of Alternatives • Lifecycle Cost Estimate • OSED • CONUSE	**2. Investment Analysis Readiness Decision *(formerly JRC 1)***

AMS Lifecycle Phase	SE Milestone Entry Criteria	SE Milestone	SE Milestone Output (SE Products Only)	AMS Investment Decision Gate
	Alternatives • SLMN			
Investment Analysis				
Initial	• Preliminary Exhibit 300 Attachment 1 (pPR - previously the iRD) • Constraints • FAA Policy • Standards • Integrated Master Schedule (IMS) • Investment risks	**Functional Baseline Review (FBR)** — A formal review to ensure that requirements have been completely and properly identified and that there is a mutual understanding between the implementing organization and stakeholders. It captures functional requirements that result from Mission Analysis and Investment Analysis phases.	• Final Requirements Set - Exhibit 300 Attachment 1 (fPR — previously the Final Requirements Document (fRD) • Program Work Breakdown Structure (WBS) • Program Statement of Work (SOW) • Final System Engineering Management Plan (SEMP)	**3. Initial Investment Decision *(formerly JRC 2a)***
Final	• final Program Requirements (fPR) • Architecture Impacts • Risks • IMS • Life Cycle Engineering (LCE) cost estimate of each alternative • Draft Interface documents	*(Program level)* **System Requirements Review (SRR)** — An internal FAA review to ensure that all the top-level requirements have been completely and properly identified and are correct. It is generally conducted just prior to AMS Investment Milestone 4. It validates program cost, schedule, and performance to support Milestone approvals. It establishes the Allocated baseline as the governing technical description, which is required before proceeding to the next	• System Specification • Risks for recommended alternative • LCE cost estimate for recommended alternative • Draft ISR Checklist • Interface documents • (Contractor) SOW	**4. Final Investment Decision *(formerly JRC 2b)***

AMS Lifecycle Phase	SE Milestone Entry Criteria	SE Milestone	SE Milestone Output (SE Products Only)	AMS Investment Decision Gate
		AMS phase.		
Solution Implementation				
	• System specification • SOW • Contract WBS	*(Contractor level)* **System Requirements Review (SRR)** — A formal, system-level review conducted to ensure that system requirements have been completely and properly identified and that a mutual understanding between the government and contractor exists.	• Agreement on system specifications	
Preliminary design	• Completed allocated baseline as documented in design specifications for each hardware and software configuration item	**Preliminary Design Review (PDR)** — A formal review of initial design concepts and documentation to confirm the preliminary design logically follows the SRR findings, meets requirements, and to further define physical and functional interface requirements. It normally results in approval to begin detailed design.	• (Approval to begin detail design) • Risks • Request for Action (RFA)	
Detail design	• Completed design package for each hardware and software configuration item	**Critical Design Review (CDR)** — A formal review conducted to evaluate the completeness of the design, its interfaces, and suitability to start initial manufacturing.	• (Approval to begin fabrication) • Risks • RFA	

AMS Lifecycle Phase	SE Milestone Entry Criteria	SE Milestone	SE Milestone Output (SE Products Only)	AMS Investment Decision Gate
Verification	• System definition is under formal configuration control • All verification plans approved • Draft verification procedures available • Verification assets/resources identified and available	**Verification Readiness Review (VRR)** — A formal review conducted to ensure that all SE considerations are satisfied and that the readiness of all support, test, and operational systems is in order to perform the Verification process.	• (Approval to begin formal verification) • Risks • Detailed verification procedures	
Verification (continued)	• Verification program complete • Reports approved • Verification article configuration compliance to design package established	**Functional Configuration Audit (FCA)** — A formal review to verify that the system and all subsystems can perform all of their required design functions in accordance with their functional and allocated configuration baselines.	• Configuration reconciliation list • Gap of required versus verified performance	
	• Technical data package complete • Quality control results available • Manufacturing and quality control plans complete • FCA complete • Configuration differences between FCA and PCA units reconciled	**Physical Configuration Audit (PCA)** — A formal audit that establishes the product baseline as reflected in an early production configuration item. The audit determines whether the system was built in accordance with the design package reviewed at the CDR.	• Baselined hardware and software configuration • Operator and user manuals	**5. In-Service Decision** ***(same)***

AMS Lifecycle Phase	SE Milestone Entry Criteria	SE Milestone	SE Milestone Output (SE Products Only)	AMS Investment Decision Gate
In-Service Management				
	• Lifecycle metrics and benefits • Operational Risk list	**In-Service Performance Review (ISPR)** — A formal technical review to characterize In-Service technical and operational health of the deployed system by providing an assessment of risk, readiness, technical status, and trends in a measurable form that will substantiate In-Service support, budget priorities, and/or possible disposal.	• Continued investment recommendation	

3.4 AMS Program Phases

3.4.1 Mission Analysis Phase

3.4.1.1 Mission Analysis Phase Objectives

The basic objectives of the Mission Analysis (MA) phase are to identify a capability shortfall, quantify a need, and identify potential technological opportunities to address that need. Nonmaterial solutions are also evaluated during this phase. In most cases, the MA consists of activities to validate high-level needs and to seek approval to proceed to the Investment Analysis phase. Mission Analysis has two dimensions: a technical dimension and a program-planning dimension. The technical dimension ensures that a complete understanding of the demand for services has been identified and quantified. This is accompanied by identification and quantification of existing and projected supply of services. The program-planning dimension identifies potential project-scope and estimated resource requirements. The primary outputs of this phase are the final Service Level Mission Need (SLMN); a preliminary Program Requirements (pPR) set documented in a Preliminary Exhibit 300 Attachment 1; definition of Alternatives; a Concept of Use; and an Initial Investment Analysis Plan. The MA phase ends with approval to execute the Investment Analysis Plan, which is obtained at the Investment Analysis Readiness Decision (see Decision #2 in Figure 3.3-1). Figure 3.4-1 is an overview of the primary SE activities that occur during MA.

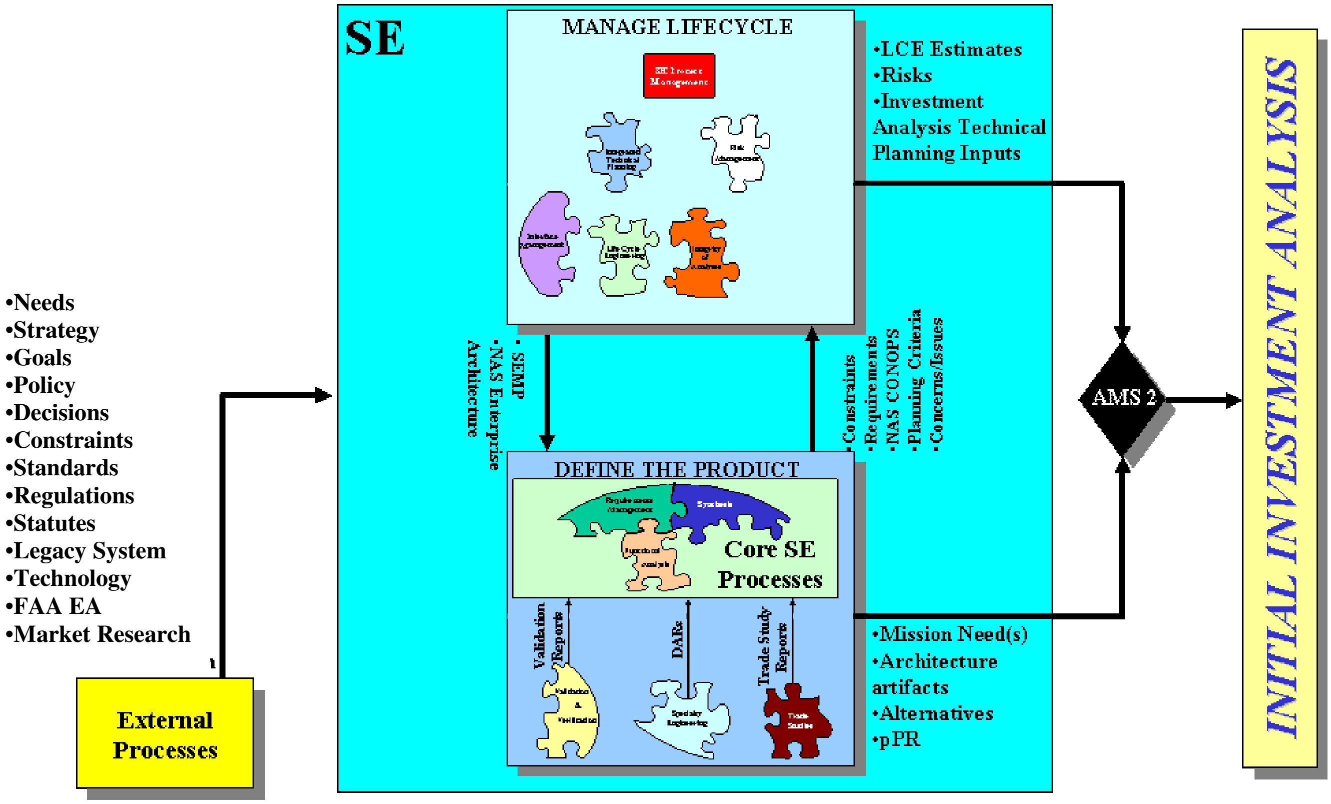

Figure 3.4-1. Mission Analysis System Engineering Inputs and Outputs

3.4.1.2 Mission Analysis SE Activities

SE is initiated when a stakeholder need is recognized and is used to understand what is required functionally to meet the stated need. A system Concept of Use (CONUSE) is developed via Functional Analysis (Section 4.4) and is used by Requirements Management (Section 4.3) to develop an SLMN to address the need or shortfall. The interaction of these two processes results in a high-level functional decomposition and, likewise, a high-level requirements decomposition. The resulting set of requirements is validated and is used, along with the high-level functional architecture, during the Synthesis process (Section 4.5) to develop a description of alternatives and associated design constraints. In addition to the core Functional Analysis, Requirements Management, and Synthesis activities, other SE processes are initiated during the MA phase. These activities involve technical planning to provide program management and guidance on planning both management and SE activities throughout the system's lifecycle. This planning is required to provide proper guidance for SE activities, including identifying risks and plans to mitigate those risks and establishing analysis criteria for the various analyses that occur during system design. Any of the SE activities may surface concerns and issues for handling by Risk Management (Section 4.10) as well as constraints to bound the activities of the Trade Studies process (Section 4.6).

EIA standard 731 defines a constraint as (1) a restriction, limit, or regulation or (2) a type of requirement that is not tradable against other requirements. Often, constraints are defined in work-scope statements provided by project contributors during the cost definition process. This includes gathering stakeholder inputs on "needs," system constraints (costs, technology limitations, and applicable specifications and legal requirements), and system "drivers" (such as competition capabilities and critical environments). It is recommended that tradeoffs be done regarding the desirability of including a performance capability in the system versus a more affordable (or less risky) system approach. This tradeoff process often begins well before a firm set of needs is established and continues throughout the MA phase during which stakeholder interaction on specific items proposed may occur. Constraints may be further adjusted throughout later AMS phases. Like behavior deficiencies or shortfalls, these are excellent opportunities for preplanned product improvement. Funding, personnel, facilities, manufacturing capability, critical resources, or other reasons may cause constraints. The reason for each constraint needs to be readily understood.

3.4.2 Investment Analysis Phase

3.4.2.1 Investment Analysis Phase Objectives

The Investment Analysis phase of the AMS lifecycle has the following objectives:

- Further translate the SLMN and supporting requirements into lower level requirements and eventually into functional specifications
- Select the balanced solution that meets cost, schedule, performance, and political considerations
- Refine the solution from a NAS perspective
- Modify the NAS enterprise architecture to the recommended solution
- Complete all program plans
- Complete the functional architecture to a level appropriate to requirements (i.e., those levels needed to support development of the final requirements and system specification*)*
- List and analyze risks associated with alternatives considered
- Provide risk mitigation plans with associated costs

The Investment Analysis phase of the AMS begins with the IARD and ends with a Final Investment Decision. The readiness decision determines whether the SLMN, CONUSE, preliminary requirements, and initial alternatives are sufficiently defined to warrant entry into investment analysis. The decision is made within context of all ongoing and planned investment activities to sustain and improve service delivery.

There are two stages of the Investment Analysis phase: the initial stage, which leads to selection of the alternative(s) offering the most promising benefits during AMS Decision Gate #3; and the final stage, which fleshes out the implementation details of the selected alternative(s) for an investment decision to authorize implementation at AMS Decision Gate #4. This section treats Investment Analysis as a single phase with intermediate SE milestones, activities, and AMS decision criteria.

3.4.2.2 Investment Analysis SE Activities

Figure 3.4-2 lists the SE elements involved during the initial stage of Investment Analysis. The Functional Analysis (Section 4.4) initiated in the prior AMS phase continues to decompose functions to lower levels. These lower level functions are used to develop more detailed requirements that are, in turn, used to bound the next level of functional decomposition. Specialty Engineering (Section 4.8) feeds this process by providing various Design Analysis Reports to further refine the requirements and manage various risk facets. Requirements generated from this interaction are validated and provided to the Synthesis process (Section 4.5), where alternative solutions to meet these requirements are developed and refined. A business case is developed that documents all stakeholder costs and obligations, providing details of both agency and nonagency resource demands.

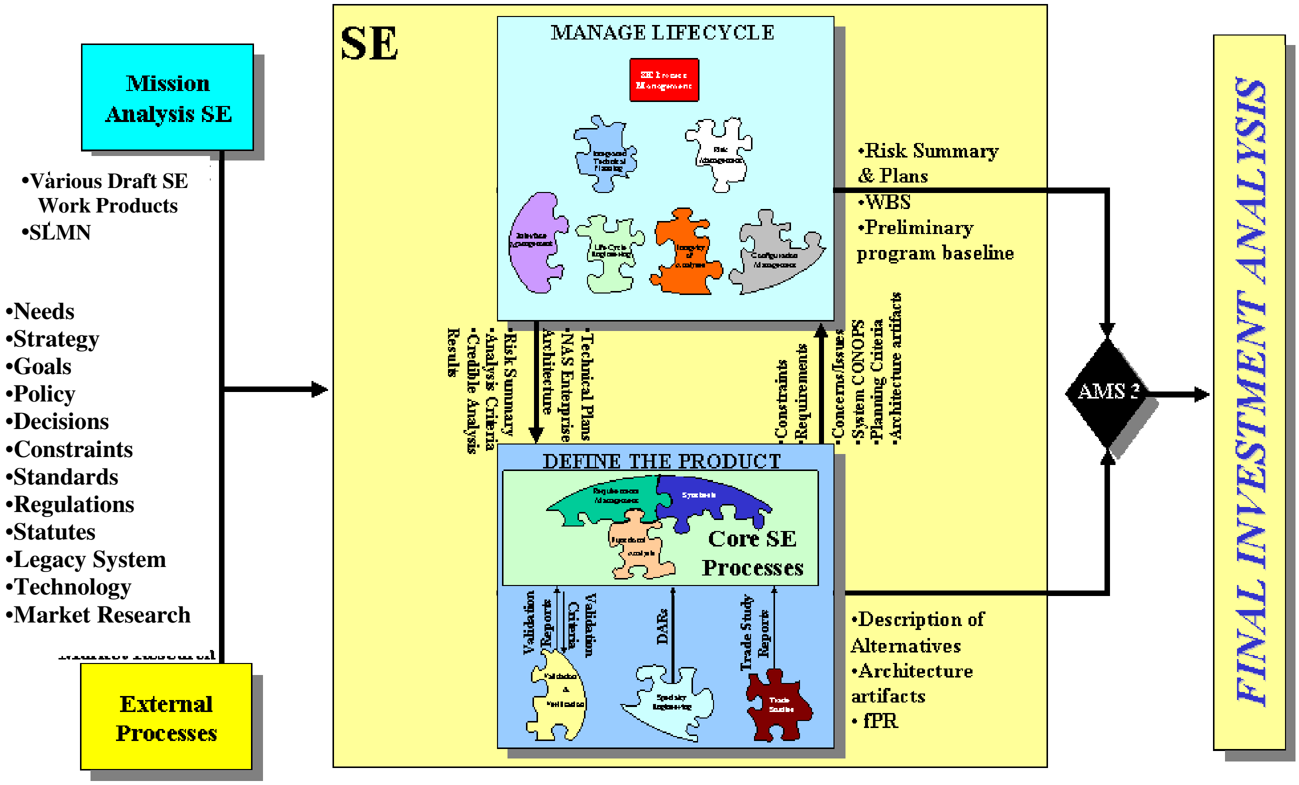

Figure 3.4-2. Initial Investment Analysis System Engineering Inputs and Outputs

When the business case sufficiently matures, the results of the initial analysis efforts and recommendations are presented to the JRC for approval to pursue the preferred solution. Implementation of that decision involves continued refinement of the business case and the SE products that support it. Figure 3.4-3 lists the SE elements involved during the second portion of Investment Analysis.

The primary outputs from the SE efforts in this AMS phase are the functional and physical architectures and associated requirements that are used to support a decision to invest in the selected solution. Table 3.3-1 (above) shows the SE products, inputs, and outputs required to complete the associated AMS milestones #3 and #4, which are the major AMS investment decision gates for this lifecycle phase.

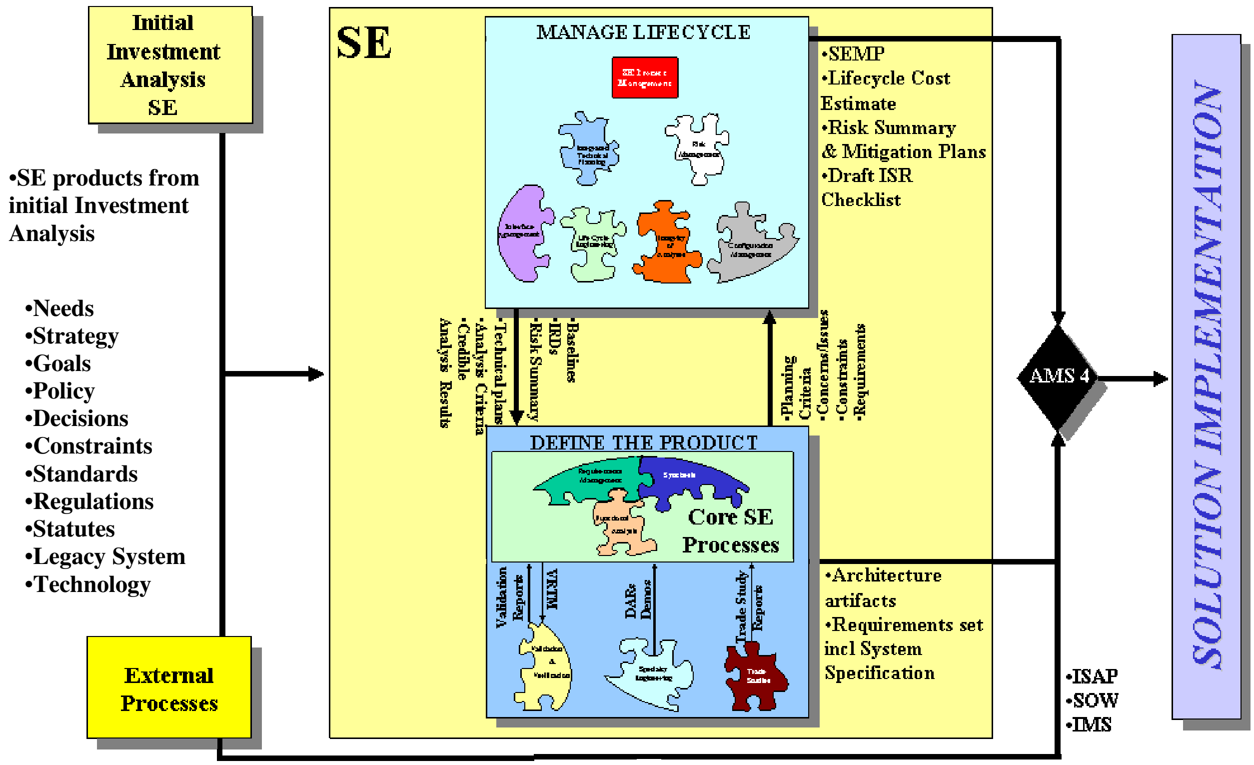

Figure 3.4-3. Final Investment Analysis System Engineering Inputs and Outputs

3.4.3 Solution Implementation Phase

3.4.3.1 Solution Implementation Phase Objectives

The Solution Implementation phase of AMS begins with the final Investment decision (AMS Decision Point #4), during which an acquisition program is established for the solution selected and ends when the new capability goes into service (i.e., when a new service or capability is commissioned into operational use at all sites).

Detailed program planning, including the solicitation and evaluation of offers for prime contract(s), occurs during final investment analysis and before the final investment decision. This ensures that accurate contract costs, risks, and schedules are reflected in the Exhibit 300 Program Baseline and its attachments. These plans and baselines are revalidated and updated if necessary after contract award to ensure that they can realistically serve as the management construct for program implementation. The Exhibit 300 Program Baseline and its attachments are maintained and kept current throughout Solution Implementation.

The overarching goal of Solution Implementation is to satisfy user requirements and achieve the benefit targets in the Exhibit 300 Program Baseline. Activities that occur during Solution Implementation vary widely and are tailored for the solution or capability being implemented. The primary outcome of Solution Implementation is a fully deployed and supported operational capability that satisfies requirements, is accepted by users, is compatible with other products and services in the field, and realizes the benefits in the program baseline.

3.4.3.2 SE Activities of Solution Implementation Phase

Figure 3.4-4 lists the SE elements activities required to accomplish the Solution Implementation objectives. While the SE activities vary widely from program to program, the interactions of the SE elements remain essentially the same as in the Investment Analysis phase. Upfront activities involve finalizing and baselining the system, its requirements, and the program to support its development and operation. The SE effort then focuses on transforming the accepted requirement set into a product for deployment. Thus, toward the beginning of the phase, the emphasis remains on the core SE processes, which continue to refine the requirements and bring greater resolution to the design. In the latter portion of this phase, the emphasis shifts to Verification activities (Section 4.12) to verify that the system has been built and integrated according to the requirements. The final set of Solution Implementation activities consists of installing the product or initiating the service at each site and certifying it for operational use. As in previous stages of SE efforts, it is recommended that each SE element active during this phase surface concerns and issues that present risk to the program.

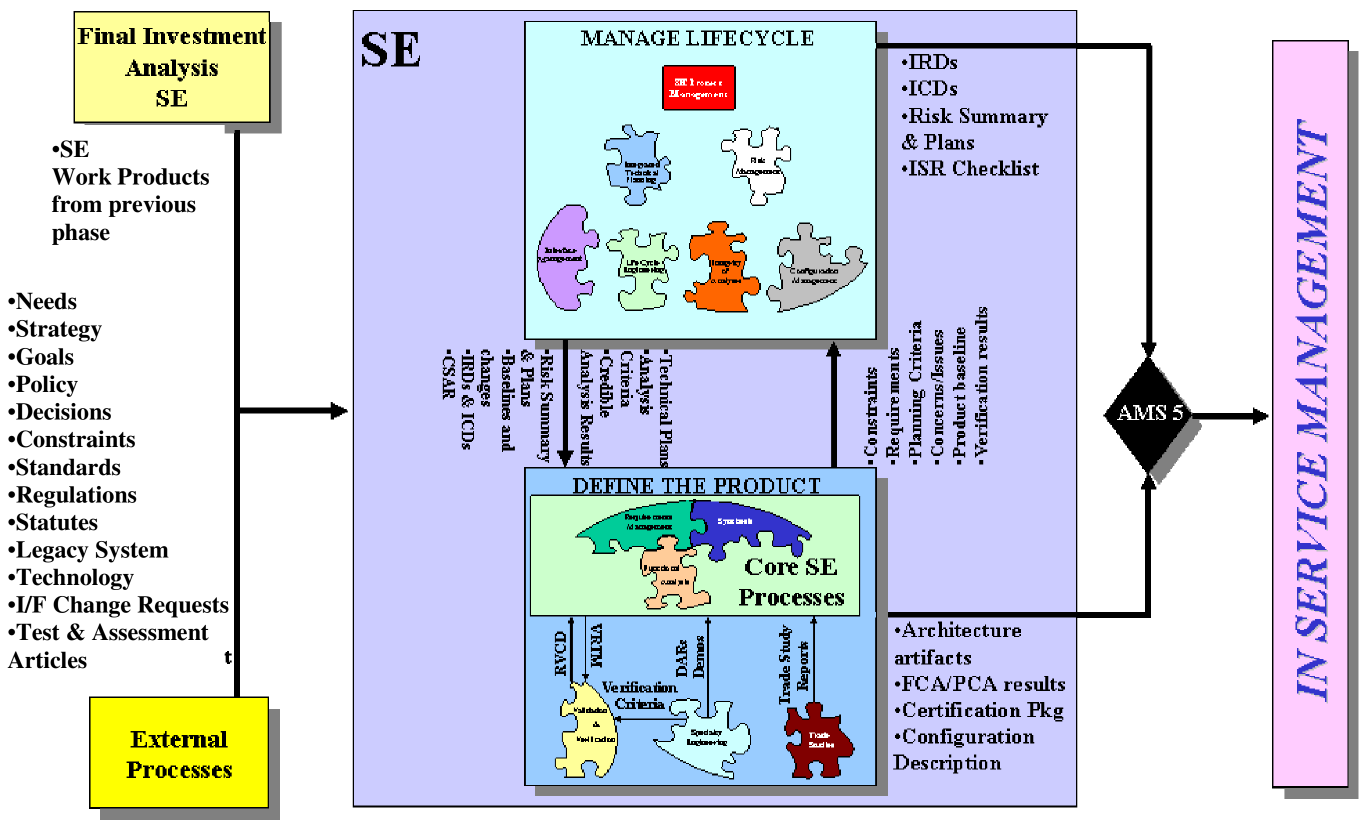

Figure 3.4-4. Solution Implementation System Engineering Inputs and Outputs

Various SE milestones—in the form of reviews and audits (discussed in Section 4.2 (Integrated Technical Planning) and illustrated in Figure 3.3-1) — are conducted throughout the development effort to maintain proper oversight of system development and maturation.

Depending on the nature and scope of the acquisition involved, the SE activities conducted during Solution Implementation vary widely. For example, activities associated with buying and deploying a commercial product involve different tasks and risks than a product requiring full development. The main objective of this phase is to successfully complete the necessary actions and activities to obtain the solution and to accept a product or service for operational use. For most acquisitions, the solution will be required to interface with at least some segment(s) of the NAS legacy system.

3.4.4 In-Service Management

In-Service Management involves two distinct sets of work activities. The first set monitors and assesses the real-world performance of the system against its requirements and expected benefits in the approved program baseline and takes action to optimize performance throughout its operational life. The second set of activities deals with operating and maintaining the system and its physical and support infrastructure throughout its service life. Both sets employ the various SE elements that appear in Figure 3.4-5. The results of SE efforts are used to support the decision-making process regarding when a new or improved capability is needed.

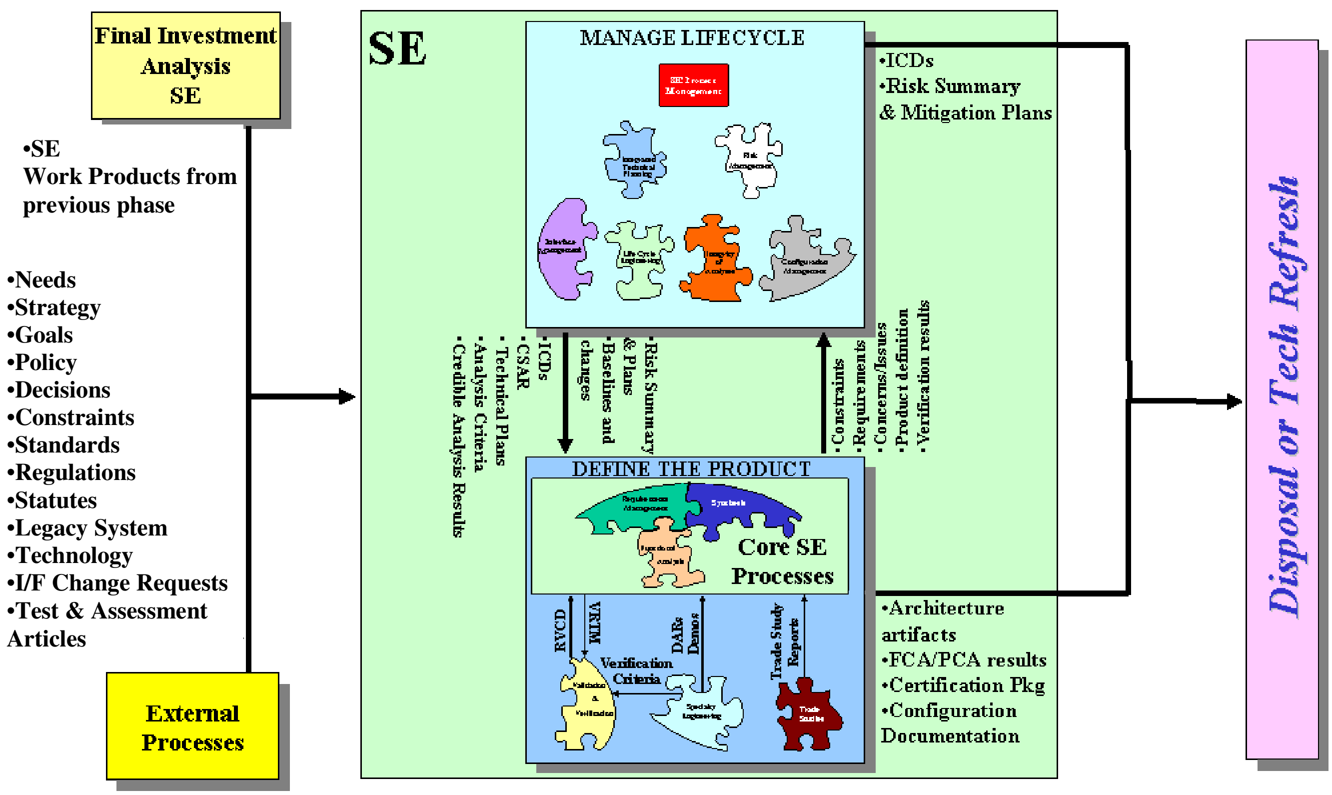

Figure 3.4-5. In-Service Management System Engineering Inputs and Outputs

In-Service decision making needs to take two factors into account: (1) assessing the timing for technology insertion or capability replacement, and (2) whether modifications or improvements are feasible within the approved sustainment baseline funding. If an engineering change to the system within the sustainment funding is unable to be supported, then the shortfall is addressed via the standard AMS lifecycle phases. If the effort to modify and/or optimize system performance is within the scope of sustaining funds, then the various SE elements are employed as in the Solution Implementation phase but on a lesser scale. The specific SE process application and associated level of effort depend on the scope of the upgrade.

3.4.5 Disposal

The SE efforts concerning disposal of a legacy system occur during the investment analysis of potential replacement alternatives and are shown in Figure 3.4-6. Disposal of the legacy system occurs during the replacement solution's Solution Implementation phase. Lifecycle Engineering (Section 4.13) defines the process for planning and executing disposal activities. The Integrated Technical Planning process (Section 4.2) is used to develop a Disposal Plan under FAA Order 4800.2, Utilization and Disposal of Excess and Surplus Personal Property.

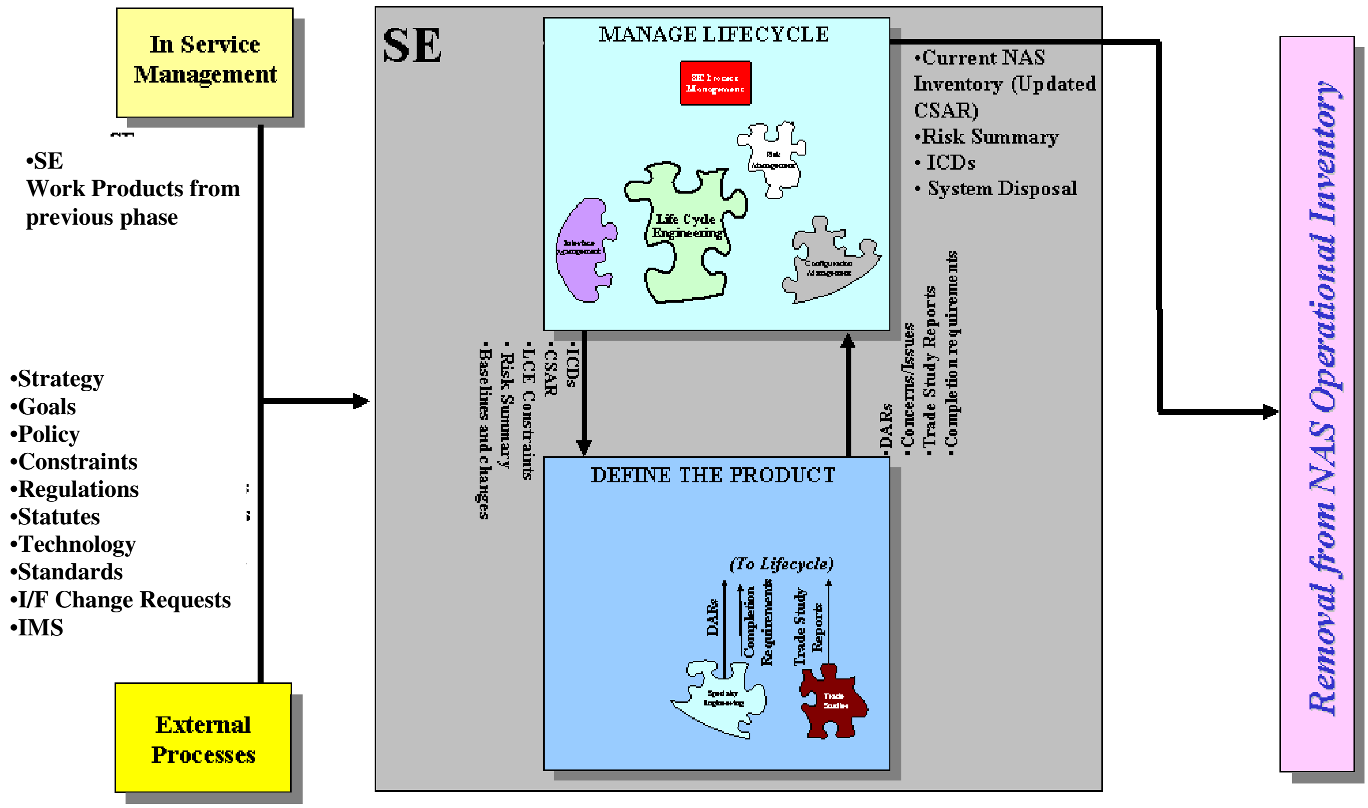

Figure 3.4-6. Disposal Phase System Engineering Inputs and Outputs